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FINAL REPORT

GRANT #: N00014-96-1-0608

PRINCIPAL INVESTIGATOR: Bruce R. Mate, Ph.D.

INSTITUTION: Oregon State University

GRANT TITLE: An assessment of gray whale movements in acoustically changing nearshore environments

AWARD PERIOD: 1 March 1996 - 30 September 1999

OBJECTIVE: The initial objective of this research was to investigate the movements of gray whales in environments with varying levels of development and acoustic stimuli. The objective broadened to: 1) identify the migration, feeding and reproductive habitats of whales and 2) develop baseline information on natural variability in whale-utilized environments where there are human activities.

APPROACH: To meet the initial objective, the approach was to examine and compare the movements of gray whales in three major breeding and calving grounds of Baja California Sur, Mexico: 1) an undeveloped lagoon where there is limited tourism and anthropogenic noise (San Ignacio); 2) adjacent to a highly developed industrial area (Laguna Ojo de Liebre); and 3) a lagoon with little industrial development, but very heavy small boat-based tourism (Magdalena Bay). Difficulty in obtaining Mexican permits prevented us from tagging in the latter two areas, prohibiting the realization of our initial objective.

Subsequently ONR permitted us to study humpback and blue whale movements and provide information relevant to management in areas where whale distribution and human activity overlap. To meet this objective, we tagged whales with Argos (satellite-monitored) radio tags to track them from known areas into previously undiscovered habitats. Humpback whales off Hawaii and blue whales off California were the focus of these studies. Locations of tagged whales are correlated with oceanographic features (bottom topography, water mass boundaries, upwelling, etc.) to better understand how whales utilize their environment (i.e. find food, migrate, etc.). Whale movements will show how some species tolerate, or are at risk from human activities.

ACCOMPLISHMENTS: ONR funding helped support six field seasons over a four year period.

In February 1996, 12 gray whales (six single animals and six females with calves) were tagged in San Ignacio Lagoon. Mothers stayed in the lagoon longer, moved less distance daily, and left the lagoon less frequently than single whales. Manuscript in near final form.

One of these tagged whales was tracked during its 1794 km northbound migration from Baja California Sur, Mexico to north of San Francisco from 8-23 February 1996. The migration route was predominantly nearshore and in water <100 m deep with 75% of the Argos-acquired locations averaging 7.3 ± 1.22 km from shore. Distances >20 km from shore and

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water depths >100 m were encountered only when the whale crossed Vizcaino Bay, Baja California, or through the Channel Islands. During migration, the whale maintained an average speed of 134 km/d (5.6 km/h), suggesting a coastal migration of 49 days from San Ignacio Lagoon to the Bering Sea. Paper submitted.

In 1998, humpback whales were tagged off Baja (seven animals) and off Hawaii (10 animals). Tags on Baja humpbacks stopped transmitting within two weeks. Believing this to be the result of tag loss, modifications were made to tag attachments which successfully improved tracking duration for our Hawaii tags. Tagged Hawaiian humpbacks provided information about movements on the breeding grounds, migration to feeding areas along British Columbia and Alaska, and movements within the feeding grounds. One humpback was tracked for 4000 km as it traveled to the Queen Charlotte Islands off British Columbia in 30 days (5.6 km/hr) before heading north toward Alaska where it was tracked for an additional 87 days.

Nine blue whales were tagged off California in 1998. Animals were tracked as they moved throughout their summer feeding areas and during their southward fall migration along the Baja California coast and beyond. Four animals spent one month each off Magdalena Bay, identifying a potential offshore feeding area. One blue whale was tracked to an area west of the Costa Rican Dome approximately 950 km offshore, where the California population likely breeds/calves. This whale set a new tracking record of 167 days. Two related papers published.

In 1999, 11 humpbacks were tagged off Hawaii (eight biopsy samples were also obtained) revealing local movements on the breeding/calving grounds, migratory movements to feeding areas along Alaska and the Aleutian Islands, and movements on the feeding grounds. One humpback was tracked for 142 days and close to 13,000 km as it traveled around Hawaii and then to the Aleutians, meandering midway in its migration for 50 days apparently feeding in an area of sea mounts and high primary productivity (paper in prep.)

Eleven blue whales were tagged off California in 1999 and tracked as they moved within their feeding grounds, both around the Channel Islands and up to the Farallon Islands off San Francisco. The timing and route of their southward migration was also tracked.

CONCLUSIONS: The 1996 San Ignacio experiment revealed differences in lagoon usage and residency time between single animals and mother/calf pairs. Our tagging took place at a time of year when the percentage of single whales usually declines, however, likely influencing lagoon residency time for these animals. The issue of residency time and hence "turn over" of both singles and mothers is important in order to establish how many whales actually use the lagoon during the winter reproductive season.

Our data confirm that gray whales are primarily nearshore migrators, but are also capable of taking the shortest route across large bays or bights.

Our humpback whale work revealed that humpbacks move widely throughout the Hawaiian Islands during their breeding season, with all but one visiting two or more islands. On average, Hawaiian humpbacks tagged in February 1999 left the breeding/calving grounds within a few weeks like those we tagged in March and April, suggesting that individual whales do not remain in Hawaii for the entire reproductive season (December to April).

Tagged blue whales traveled to the Costa Rican dome, linking the California feeding area with a potential breeding/calving area in the eastern tropical Pacific. Whale locations also revealed a potential feeding area out to 100 km west-southwest of Magdalena Bay within a narrow 2° C-wide temperature band. Locations within California showed wide-ranging north-south movement (southern California to Oregon) of up to 150 km/day. They also revealed that tagged animals move quickly from nearshore to offshore areas, suggesting whales in these areas comprise a single stock. Blue whales appeared to have synchronous migratory timing south of Cabo San Lucas.

SIGNIFICANCE: Our tracking shows the northbound migration route and rate of speed of an individual gray whale for the very first time. Their nearshore migration takes them through areas with considerable human activity.

Many more humpbacks use Hawaii as a breeding/calving area than can be counted at any one time (survey). Further, 75% of all humpbacks using Hawaii probably migrate to some area other than SE Alaska, where most fluke identifications have been made. Wide scale movements within Hawaiian waters suggest considerable flexibility for humpbacks, reducing the risk that a single, short-term human activity with adverse impact in one area will greatly affect the entire population. Movement patterns in feeding areas suggest good "memory" of productive areas and regionally specific matrilineal relationships of whales with similar patterns.

Blue whales concentrate their nearshore activities in areas of upwelling typically in water >100 fathoms, but may be at risk from ship collisions near the Farallon Islands off San Francisco and in the Santa Barbara Channel approach to Los Angeles. Whales may migrate to productive areas for their winter breeding/calving season where they can continue to feed, unlike gray and humpback whales which fast.

PATENT INFORMATION: No patents have been obtained.

AWARD INFORMATION: None received during the period of this grant.

PUBLICATIONS AND ABSTRACTS:

Fiedler, P., S. Reilly, R. Hewitt, D. Demer, V. Philbrick, S. Smith, W. Armstrong, D. Croll, B. Tershey, B. Mate. 1998. Blue whale habitat and prey in the Channel Islands. *Deep-Sea Research II*. 45:1781-1801.

Lagerquist, B.A., K.M. Stafford, and B.R. Mate. (in press). Dive characteristics of satellite-monitored blue whales (*Balaenoptera*

musculus) off the Central California Coast. *Marine Mammal Science*. 16(2).

Mate, B.R. and J. Urban-Ramirez. (Submitted). The route and speed of a gray whale on its northern migration from Mexico to Central California tracked by satellite-monitored radio tag. *Marine Mammal Science*.

Mate, B.R., B. A. Lagerquist, and J. Urban-Ramirez. (Submitted). The use of San Ignacio Lagoon by breeding and calving gray whales. *Marine Mammal Science*.

Mate, B.R., R. Gisiner, and J. Mobley. 1998. Local and migratory movements of Hawaiian humpback whales tracked by satellite telemetry. *Canadian Journal of Zoology*. 76: 863-868.

Mate, B.R., B.A. Lagerquist, and J. Calambokidis. 1999. The movements of North Pacific blue whales off Southern California and their southern fall migration. *Marine Mammal Science*. 15(4): 333-344.

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13. ABSTRACT (Maximum 200 words) This grant helped fund six field seasons over four years. The initial objective was to investigate the movements of gray whales in environments with varying levels of development and acoustic stimuli. The objective eventually broadened to identify the critical habitats of whales and investigate how natural variability and human activities affect the ways endangered whales utilize their environments. To accomplish these objectives, gray whales (1996) and humpbacks (1998) were tagged in Baja, blue whales were tagged along California (1998-99), and humpbacks were tagged around Hawaii (1998-99). The detailed route and rate of a gray whale's northbound migration was determined. Female gray whales with calves stayed in lagoons much longer than singular whales (\bar{x} =22 days) suggesting the importance of these areas for development of new born calves. We determined: Hawaiian humpbacks' movements in and around the winter reproductive grounds, various spring migration routes, new feeding areas, associations with oceanographic features, and movement patterns within the feeding grounds. Tagged blue whales were tracked during their feeding season off California, south along the Baja coast during their fall migration and to an upwelling area near the equator which is likely where some of the population goes to breed and calve.					
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